CLAIMS

1. A device for detecting charged particles in a fluid comprising:

   a) a microchannel comprising an inlet for introducing said fluid into said microchannel;

   b) a pair of electrodes for applying a voltage to produce an electrical field across said microchannel orthogonal to the length of said microchannel; and

   c) means for detecting the position of said charged particles within said microchannel after application of said voltage.

2. The device of claim 1 also comprising means for identifying said charged particles by correlating the detected position of said charged particles with the position of charged particles of known identity.

3. The device of claim 1 also comprising means for determining the initial concentration of said particles in said fluid.

4. The device of claim 1 wherein the microchannel comprises a fluid, and a pH gradient is formed across said fluid.

5. The device of claim 1 wherein the microchannel comprises a fluid, and a concentration gradient is formed across the channel.

6. The device of claim 1 wherein the distance between said electrodes is from about 10 μm to no greater than about 5 mm.

7. The device of claim 1 wherein said electrodes form walls of said microchannel.

8. The device of claim 1 wherein said electrodes are capable of applying a voltage from about 0.1 V to no greater than about 5 V.

9. The device of claim 1 also comprising quantitation means for determining the concentration of said particles.

10. The device of claim 1 wherein said microchannel contains said fluid, and said electrodes are prevented from direct contact with said fluid by a layer of sheath fluid in laminar flow with said fluid.

11. The device of claim 1 wherein said microchannel contains a fluid comprising particles having differing electrophoretic mobilities.

12. The device of claim 1 wherein said means for detecting is capable of detecting the position of a plurality of particles having differing electrophoretic mobilities within said channel after application of said voltage.

13. The device of claim 1 also comprising means for changing the polarity of said electric field.

14. The device of claim 1 wherein said device comprises one or more additional sets of electrodes positioned downstream from said pair of electrodes.

15. The device of claim 14 wherein at least one additional set of electrodes has a polarity opposite to that of said pair of electrodes.

16. A method for detecting charged particles in a fluid comprising:

a) introducing a fluid containing charged particles into a microchannel through an inlet;

b) applying a voltage to produce an electrical field across said microchannel orthogonal to the length of said microchannel to cause said charged particles to migrate to a position in said microchannel; and

c) detecting the position of said charged particles within said microchannel after application of said voltage.

17. The method of claim 16 also comprising reversing the polarity of said voltage.

18. The method of claim 17 comprising reversing the polarity of said voltage a plurality of times.

19. The method of claim 16 comprising applying different voltages or polarities to said microchannel at different points along its length.

20. A device for separation of particles of a first selected electrophoretic mobility in a fluid comprising particles of at least one other selected electrophoretic mobility, comprising:

a) a microchannel comprising an inlet for introducing said fluid into said microchannel;

b) a pair of electrodes for applying a selected voltage to produce an electrical field across said microchannel orthogonal to the length of said microchannel;

c) a first outlet in said microchannel placed to receive a first outlet portion of said fluid containing an enhanced concentration of said particles of said first selected electrophoretic mobility after application of said electrical field; and

d) at least a second outlet in said microchannel placed to receive a second outlet portion of fluid containing an enhanced concentration of particles of a second selected electrophoretic mobility.

21. A device of claim 20 also comprising detection means for detecting the presence of said particles in said microchannel or in an outlet portion of said fluid.

22. The device of claim 20 wherein the distance between said electrodes is from about 10 μm to no greater than about 5 mm.

23. The device of claim 20 comprising one or more additional sets of electrodes positioned downstream from said pair of electrodes.

24. The device of claim 20 also comprising means for changing the polarity of said electric field.

25. The device of claim 20 wherein said electrodes form walls of said microchannel.

26. The device of claim 20 wherein at least said first outlet is in a side wall of said microchannel.

27. The device of claim 20 wherein said electrodes are capable of applying a voltage from about 0.1V to no greater than about 5 V.

28. The device of claim 20 also comprising quantitation means for determining the concentration of particles.

29. The device of claim 28 wherein said quantitation means are capable of determining the initial concentration of particles in said fluid.

30. The device of claim 20 also comprising a third outlet in said microchannel placed to receive a third outlet portion of fluid containing an enhanced concentration of particles having a third selected electrophoretic mobility.

31. The device of claim 20 also comprising a plurality of additional outlets in said microchannel, each placed to receive portions of fluid containing an enhanced concentration of particles having different selected electrophoretic mobilities.

32. The device of claim 20 wherein at least said first outlet is placed in a channel wall adjacent to or formed by one of said electrodes.

33. The device of claim 20 where a plurality of said outlets are placed in a channel wall adjacent to or formed by one of said electrodes.

34. The device of claim 20 not comprising means for extracting or diverting bubbles from said microchannel.

35. The device of claim 20 containing said fluid in said microchannel

36. The device of claim 35 wherein said particles are selected from the group consisting of proteins, nucleic acid molecules, microorganisms and cells.

37. The device of claim 20 wherein said microchannel contains a fluid comprising selected particles, and has a second inlet for introducing a fluid comprising an electrophoretic mobility-adjusting particle capable of binding to said selected particles and producing particles of said selected electrophoretic mobility.

38. The device of claim 37 wherein said electrophoretic mobility-adjusting particles are selected from the group consisting of antibodies, polymers, nucleic acids, and combinations thereof.

39. The device of claim 20 containing a flowing stream of said fluid in said microchannel.

40. The device of claim 20 comprising at least one sheath fluid stream in said microchannel between an electrode and said particles to be separated.

41. The device of claim 40 comprising at least one additional inlet for providing said sheath fluid.

42. The device of claim 40 comprising at least one additional outlet for removing said sheath fluid.

43. The device of claim 20 wherein said outlets are on the downstream end of said microchannel.

44. The device of claim 20 wherein said outlets are on one electrode wall of said microchannel.

45. The device of claim 20 wherein said outlets are on opposite electrode walls of said microchannel.

46. The device of claim 20 wherein one outlet is on the downstream end of said microchannel and one outlet is on an electrode wall of said microchannel.

47. A device for mixing particles contained in a first fluid into a second fluid comprising:

a) a microchannel comprising a first inlet placed to introduce said first fluid containing said particles into said microchannel;

b) a second inlet in said microchannel placed to introduce said second fluid stream into said microchannel in laminar flow with said first fluid;

c) a pair of electrodes for applying an electrical field across said microchannel orthogonal to the length of said microchannel, said electrical field being sufficient to cause at least a portion of said particles to move into said second fluid; and

d) an outlet placed to receive said second fluid containing at least a portion of said particles.

48. The device of claim 47 containing said first and second fluids.

49. The device of claim 47 containing flowing streams of said first and second fluids.

50. The device of claim 47 wherein said second fluid is a dilution stream.

51. A method for separating particles of a first selected electrophoretic mobility from a fluid comprising particles of at least one other selected electrophoretic mobility, comprising:

a) flowing said fluid into a microchannel;

b) applying an electrical field perpendicular to the length of said microchannel across said microchannel, whereby at least said particles of said first selected electrophoretic mobility are caused to migrate toward one electrode wall of said microchannel;

c) flowing a first outlet portion of said fluid containing an enhanced concentration of said particles of said first selected electrophoretic mobility from said microchannel through a first outlet placed to receive said first outlet portion; and

d) flowing a second outlet portion of said fluid containing an enhanced concentration of particles of a selected second electrophoretic mobility from said microchannel through a second outlet placed to receive said second outlet portion.

52. The method of claim 51 wherein said fluid is a continuously flowing stream.

53. The method of claim 51 wherein said electrical field is formed by application of a voltage high enough to cause said particles of said first selected electrophoretic mobility to concentrate at one side of said microchannel at or upstream from said first outlet.

54. The method of claim 51 wherein said electrical field is formed by application of a voltage high enough to cause said particles of said second selected electrophoretic mobility to concentrate at one side of said microchannel at or upstream from said second outlet but not at or upstream from said first outlet.

55. The method of claim 51 wherein said electrical field is formed by application of a voltage of from about 0.1V to no more than about 5 V.

56. The method of claim 51 also comprising detecting the presence of said particles in said microchannel or said first outlet portion.

57. The method of claim 51 also comprising determining the concentration of said particles.

58. The method of claim 51 also comprising determining the initial concentration of said particles in said fluid.

59. The method of claim 51 also comprising removing a fluid containing an enhanced concentration of particles having a third selected electrophoretic mobility through a third outlet placed to receive said third fluid portion.

60. The method of claim 51 also comprising removing a plurality of outlet fluids, each containing an enhanced concentration of particles having different selected electrophoretic mobilities, through plurality of additional outlets.

61. The method of claim 51 wherein said particles are selected from the group consisting of proteins, nucleic acid molecules, microorganisms and cells.

62. The method of claim 51 also comprising reversing the polarity of said voltage.

63. The method of claim 62 also comprising reversing the polarity of said voltage a plurality of times.

64. The method of claim 51 also comprising applying different voltages or polarities to said microchannel at different points along its length.

65. The method of claim 51 also comprising flowing at least one sheath fluid stream into said microchannel to prevent contact between said fluid containing particles and said electrode.

66. A method for separating selected particles from a fluid comprising said particles, comprising:

a) flowing said fluid into a microchannel having at least two electrode walls;

b) mixing with said fluid electrophoretic mobility-adjusting particles capable of binding to said selected particles to form complex particles having an electrophoretic mobility;

c) applying an electrical field perpendicular to the length of said microchannel across said microchannel sufficient to cause said complex particles to migrate toward an electrode wall of said microchannel; and

d) removing a fluid portion containing an enhanced concentration of said complex particles from said microchannel through an outlet placed to receive said fluid portion.

67. The method of claim 66 also comprising removing a second fluid portion containing an enhanced concentration of particles having a second electrophoretic mobility from said microchannel through a second outlet placed to receive said second fluid portion.

68. A method for separating a fluid having a first concentration of particles into a plurality of fluids having different concentrations of said particles comprising:

a) flowing said fluid having a first concentration of particles into a microchannel;

b) applying an electric field across said microchannel to create a concentration gradient across or down the length of said microchannel; and

c) removing a plurality of fluid streams from said microchannel through outlets positioned to extract fluid streams of different concentrations.

69. The method of claim 68 also comprising creating a pH gradient across said microchannel.

70. A method for extracting selected particles contained within a cell or organism comprising:

a) flowing a fluid containing said cell or organism into a microchannel having at least two electrode walls;

b) damaging the cell wall or outer membrane of said cell or organism;

c) applying an electrical field perpendicular to the length of said microchannel across said microchannel sufficient to cause said selected particles to migrate toward one of said electrode walls; and

d) removing an outlet portion of said fluid containing at least a portion of said selected particles from said microchannel through an outlet placed to receive said first outlet portion.

71. The method of claim 70 also comprising removing a second outlet portion of said fluid containing second particles having an electrophoretic mobility different from said selected particles through a second outlet placed to receive said second outlet portion.

72. The method of claim 70 also comprising mixing with said fluid electrophoretic mobility-adjusting particles capable of binding to said selected particles to form complex particles having a selected electrophoretic mobility and removing a fluid portion containing said complex particles from said microchannel through an outlet placed to receive said fluid portion.

73. The method of claim 70 also comprising removing a second fluid portion, in which said selected particles are reduced in concentration or absent, from said microchannel through an outlet placed to receive said second fluid portion.

74. The method of claim 70 wherein said damaging of the cell wall or outer membrane of is done by contacting said organisms with a fluid having a pH sufficient to lyse said organisms.

75. A device for separation of particles of a selected isoelectric point from a fluid stream comprising particles of other isoelectric points, comprising:

a) a microchannel containing said fluid stream and comprising an inlet for introducing said fluid stream into said microchannel;

b) a pair of electrodes for applying an electrical field across said microchannel orthogonal to the length of said microchannel sufficient to produce a pH gradient across said fluid stream and concentrate at least a portion of said particles of a selected isoelectric point into a band within said stream; and

c) an outlet in said microchannel placed to receive an outlet fluid stream containing at least a portion of said band after application of said electrical field.

76. The device of claim 75 also comprising detection means for detecting the presence of said particles in said microchannel or in an outlet portion of said fluid.

77. The device of claim 75 wherein the distance between said electrodes is from about 10 μm to no greater than about 5 mm.

78. The device of claim 75 comprising one or more additional sets of electrodes positioned downstream from said pair of electrodes.

79. The device of claim 75 also comprising means for changing the polarity of said electric field.

80. The device of claim 75 comprising means for applying a voltage from about 0.1V to no greater than about 5 V to said electrodes.

81. The device of claim 75 not comprising means for extracting or diverting bubbles from said microchannel.

82. The device of claim 75 wherein said particles are selected from the group consisting of proteins, nucleic acid molecules, microorganisms and cells.

83. The device of claim 75 wherein said electrodes form walls of said microchannel.

84. The device of claim 75 wherein at least said first outlet is in a side wall of said microchannel.

85. The device of claim 75 also comprising quantitation means for determining the concentration of particles.

86. The device of claim 75 also comprising quantitation means for determining the initial concentration of said particles in said fluid stream.

87. The device of claim 75 also comprising a second outlet placed to receive a second fluid stream containing an enhanced concentration of particles having a second selected isoelectric point different from said first selected isoelectric point.

88. The device of claim 75 comprising a plurality of additional outlets, each placed to receive a fluid stream containing an enhanced concentration of particles having different selected isoelectric points.

89. The device of claim 75 comprising said fluid stream in said microchannel.

90. The device of claim 89 wherein said fluid stream comprises at least one buffering agent.

91. The device of claim 90 wherein the pH gradient across said fluid stream is from about 2 to about 10.

92. The device of claim 90 wherein the pH gradient across said fluid stream is from about 3 to about 8.

93. The device of claim 89 wherein said fluid stream comprises an electrolyte.

94. The device of claim 93 wherein said electrolyte is a non-chloride electrolyte.

95. The device of claim 92 wherein said pH gradient is formed by electrolysis of water.

96. The device of claim 89 comprising a concentration gradient across or down the length of said fluid stream.

97. The device of claim 75 comprising at least one sheath fluid stream in said microchannel between an electrode and said particles to be separated.

98. The device of claim 97 comprising at least one additional inlet for providing said sheath fluid.

99. The device of claim 97 comprising at least one additional outlet for removing said sheath fluid.

100. The device of claim 75 also comprising a second inlet for introducing a fluid comprising an isoelectric point-adjusting particle capable of binding to said selected particles and producing particles of said selected isoelectric point.

101. The device of claim 89 wherein said particles are selected from the group consisting of proteins, nucleic acid molecules, microorganisms and cells.

102. The device of claim 89 wherein said isoelectric-point-adjusting particles are selected from the group consisting of antibodies, polymers, nucleic acids and combinations thereof.

103. A device for mixing particles contained in a first fluid into a second fluid comprising:

a) a microchannel comprising a first inlet placed to introduce said first fluid containing said particles into said microchannel;

b) a second inlet in said microchannel placed to introduce said second fluid into said microchannel in laminar flow with said first fluid;

c) a pair of electrodes for applying an electrical field across said microchannel orthogonal to the length of said microchannel, said electrical field being sufficient to cause at least a portion of said particles to isoelectrically focus in said second fluid; and

d) an outlet placed to receive said second fluid containing said particles.

104. The device of claim 103 containing said first and second fluids.

105. The device of claim 104 wherein said second fluid is a dilution stream.

106. The device of claim 104 wherein said first and second fluids are flowing streams.

107. A method for separating particles of a selected isoelectric point from a fluid stream comprising said particles, comprising:

a) flowing said fluid stream into a microchannel;

b) applying an electrical field perpendicular to the length of said microchannel across said microchannel sufficient to cause at least a portion of said particles to isoelectrically focus in said stream; and

c) flowing an outlet portion of said fluid stream containing an enhanced concentration of said particles of said selected isoelectric point from said microchannel through an outlet placed to receive said outlet portion.

108. The method of claim 107 also comprising flowing a second outlet portion of said fluid stream containing an enhanced concentration of particles of a selected second isoelectric point from said microchannel through an outlet placed to receive said second outlet portion.

109. The method of claim 108 also comprising flowing at least one further outlet portion of said fluid stream containing an enhanced concentration of particles of a selected further isoelectric point from said microchannel through an outlet placed to receive said further outlet portion.

110. The method of claim 107 wherein said electrical field is formed by application of a voltage of from about 0.1V to no more than about 5 V.

111. The method of claim 107 wherein said fluid stream comprises at least one buffering agent.

112. The method of claim 107 comprising creating a pH gradient across said fluid stream from about 2 to about 10.

113. The method of claim 107 wherein the pH gradient across said fluid stream is from about 3 to about 8.

114. The method of claim 107 wherein said fluid stream comprises an electrolyte.

115. The method of claim 107 wherein said electrolyte is a non-chloride electrolyte.

116. The method of claim 107 wherein said pH gradient is formed by electrolysis of water.

117. The method of claim 107 also comprising forming a concentration gradient across or down the length of said microchannel.

118. The method of claim 107 also comprising detecting the presence of said particles in said microchannel or said first outlet portion.

119. The method of claim 107 also comprising reversing the polarity of said voltage.

120. The method of claim 119 also comprising reversing the polarity of said voltage a plurality of times.

121. The method of claim 107 also comprising applying different voltages or polarities to said microchannel at different points along its length.

122. The method of claim 107 also comprising flowing at least one sheath fluid stream into said microchannel to prevent contact between said fluid containing particles and said electrode.

123. The method of claim 107 also comprising determining the concentration of particles.

124. The method of claim 123 also comprising determining the initial concentration of particles in said fluid.

125. The method of claim 107 wherein said particles are selected from the group consisting of proteins, nucleic acid molecules, microorganisms and cells.

126. A method for separating selected particles from a fluid stream comprising said particles, comprising:

a) flowing said fluid stream into a microchannel;

b) mixing with said fluid stream isoelectric point-adjusting particles capable of binding to said selected particles to form complex particles having a selected isoelectric point;

c) applying an electrical field perpendicular to the length of said microchannel across said microchannel to concentrate at least a portion of said complex particles at their isoelectric point; and

d) flowing a fluid portion containing an enhanced concentration of said complex particles from said microchannel through an outlet placed to receive said fluid portion.

127. The method of claim 126 also comprising removing a second fluid portion containing an enhanced concentration of particles having a second selected isoelectric point from said microchannel through a second outlet placed to receive said second fluid portion.

128. A method for extracting selected particles contained within an organism from said organism comprising:

a) flowing a fluid containing said organisms into a microchannel;

b) damaging the cell wall or outer membrane of said organisms within said microchannel to release particles therefrom;

c) applying an electrical field perpendicular to the length of said microchannel across said microchannel to form a pH gradient across said microchannel and isoelectrically focus said particles;

d) flowing a first outlet portion of said fluid containing at least a portion of said particles focused at a first isoelectric point from said microchannel through an outlet placed to receive said first outlet portion; and

e) flowing a second outlet portion of said fluid containing at least a portion of said particles focused at a second isoelectric point different from said first isoelectric point from said microchannel through an outlet placed to receive said second outlet portion.

129. The method of claim 128 also comprising mixing with said fluid electrophoretic mobility-adjusting particles capable of binding to said particles to form complex particles having a selected isoelectric point and removing a fluid portion containing said complex particles from said microchannel through an outlet placed to receive said fluid portion.

130. The method of claim 128 also comprising removing a second fluid portion in which said selected particles are reduced in concentration or absent from said microchannel through an outlet placed to receive said second fluid portion.

131. The method of claim 128 wherein said damaging the cell wall or outer membrane of is done by contacting said organisms with a fluid having a pH sufficient to lyse said organisms.

132. A device for concentrating selected particles from a fluid comprising:

a) means for sedimenting particles larger than said selected particles;

b) electrophoretic or isoelectric focusing means, in fluid communication with said means for sedimenting, for separating said selected particles from interferent particles selected from the group consisting of particles larger than, smaller than, and both larger and smaller than, said selected particles; and

c) means for analyzing said separated selected particles in fluid communication with said electrophoretic or isoelectric focusing means.

133. The device of claim 132 also comprising electrophoretic or isoelectric focusing means for concentrating said selected particles between said focusing means and said analyzing means.